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No. 1033

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By D. Fuchs

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By D. Fuchs

SUMMARY

Unduly high diving speeds can be effectively controlled by diving brakes. But their employment involves at the same time a number of disagreeable features: namely, rotation of zero lift direction, variation of diving moment, and the creation of a potent dead air region.

1. Braking effect.- The point of attachment at the wing (rear position) has the greatest influence on the braking effect; forward positions afford stronger braking action than rearward positions. At zero lift the effect is approximately the same whether the brakes are mounted on the upper or the lower surface; the mounting on the lower surface is accompanied by a marked slowing down of braking effect at increasing lift. The aspect ratio of the brake has as little effect on the braking action as the lateral position.

For the decision of the question of suitable location the braking effect can, therefore, be largely discounted, provided the brakes are placed as far forward as possible, the span being preferably so disposed that only one of the trailing edge flaps is hit by the dead-air region.

2. Rotation of zero lift direction.- The mounting of diving brakes on top of the wing produces a positive rotation (sight impairing), under the wing, a negative rotation (sight improving) of zero lift direction. The absolute amount of the angle of rotation can be reduced by a greater aspect ratio or by locating the brakes closer to the fuselage.

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*"Windkanaluntersuchungen an Bremsplatten." Luftfahrtforschung, Bd. 15, Lfg. 1/2, Jan. 20, 1938, pp. 19-27.

3. Variation of diving moment.- Limited to the explored backward positions of the brake up to about 30 percent of the chord, the sign of the moment change is (as under 2) determined by the disposition on the upper or lower surface of the wing. (Upper surface: noseheavy; bottom surface: tailheavy additional moments.) The limitation to the front portion of the profile was dictated by the fact that the split flaps mounted at the lower surface produce, as is known, additional noseheavy moments. It follows, moreover, that there always exists a point of attachment for the brake on the lower surface of the wing for which the additional moments become equal to zero. The absolute amount of moment change of the investigated brake arrangements can be reduced, as before, by greater aspect ratio and placement closer to the fuselage.

Since the diving brakes must be mounted near the spars for reasons of strength, that is, in the fore part of the profile, the use of the bottom surface is advisable because the additional tailheavy moment here unloads the diving moment. The sign of the additional moment can be explained by means of pressure distribution measurements. It was found that the low pressure behind the brake, when mounted on the lower surface of the wing, must furnish a tailheavy additional moment. The pressure distribution measurements are invaluable for static purposes, since the conventional methods under such severe disturbances render a precalculation impossible.

4. Avoidance of unwanted dead-air region effects.- Experiments in the dead-air region of the brake indicate that the provision of a gap between wing and brake affords considerable amelioration of the unwanted effects of the dead-air region. It was proved by measurements on a model airplane and on a normal wing that the provision of a gap is only beneficial, since the braking effect in any event does not slacken and the effect on diving moment and zero lift direction becomes at the same time less.

I. DISTRIBUTION OF THE BRAKE SURFACES ON THE WING

a. Distribution on Upper and Lower Surface of Wing

Brakes of 105-millimeter span each and 36.7 square centimeter area, or altogether of 73.4 square centimeter or 1.65 percent of the wing area, were mounted on a model

of 1.64 meters span with an elliptical area of 0.446 square meter on each wing half. The model wing had twist and was complete, that is, was fitted with horizontal and vertical tail surfaces, as the tests were intended to include the longitudinal moment changes of the whole airplane, hence inclusive of any eventual effects on the tail.

The tests were made with the following arrangements:

1. Brake 100 percent on lower surface

2. Brake 57 percent on lower surface and 43 percent on upper surface

3. Brake 43 percent on lower surface and 57 percent on upper surface

4. Brake 100 percent on upper surface

The reference quantities for the aerodynamic force coefficients are:

$F = 0.446\ m^2$ wing area

$t = 0.346\ m$ maximum chord

The moment reference point was 133.5 millimeters behind the envisaged wing nose in fuselage center, that is, at 38.6 percent of the maximum wing chord. The results of the tests made at $v = 30$ m/s air speed are provided with the usual corrections for open jets with elliptical section for drag and angle of attack (reference 1).

The test data are shown in figure 1 along with a reference measurement of the model without brakes. The additional drag, referred to the brake area, is shown in figure 2 (denoted with Δc_{wB}).

1. Drag.- The minimum profile drag of these arrangements is located at widely varying c_a values. Hence the polars, viewed from $c_a = 0$ in direction of ascending c_a values, present entirely different aspects. While the drag increases continuously with the brakes disposed on the "upper surface only," there still is a considerable loss in braking effect with the brake mounted on the "lower surface only." Of the drag increment existing at $c_a = 0$ only 55 percent remain at $c_a = 0.3$.

This phenomenon is noteworthy, because of the marked decrease in braking effect attending a pull-out from a dive with brake flap extended on the lower surface. It is plainly visible in figure 2.

An unusual feature is that the drag coefficients of the brakes assume such high values. Those of the same aspect ratios freely exposed give drag coefficients of the order of magnitude of 1.1 to 1.4 (reference 2). However, it is entirely comprehensible that a multiplication of drag is obtainable by mutual effect between brake and wing, especially if the former is located on top of the wing.

2. Variation of longitudinal moment.- These variations are very considerable. To estimate the approximate magnitude of change of normal force coefficient necessary at the horizontal tail surfaces which balances the produced change in longitudinal moment, we put

$$\Delta c_{nH} = \frac{Ftq}{F_H t_H q_H} \Delta c_{m_o}$$

(Subscript H denotes the horizontal tail surfaces.)

In our example it is

$$\Delta c_{nH} \approx 3 \Delta c_{m_o}$$

Extension of the brake area with arrangement "flap below only" produces a variation in diving moment of $\Delta c_{m_o} = -0.07$ and of $\Delta c_{m_o} = +0.07$ with arrangement "flap above only." Hence the normal force coefficient on the horizontal control surface must change by about $\Delta c_{nH} = \pm 0.21$ which in any event requires an elevator deflection of about 6° on the assumption of $\frac{dc_{nH}}{d\alpha} = 4$ and $\frac{d\alpha}{d\beta} = 0.5$. Noteworthy also is the sign of the moment variation, because it is contrary to natural expectation: A brake flap under the wing produces a tailheavy rather than a noseheavy moment. This is solely because of the change in pressure distribution on the profile, as will be explained elsewhere.

Still another noteworthy feature is the change of direction of the longitudinal moment line ($c_m = f(c_a)$ in the illustration) which is especially marked on the arrangement "brake flaps below only." Referred to maximum chord at mid-center of the wing there is in this instance a 11.3 percent chordwise backward displacement of the neutral point. The other moment lines of this picture are not rectilinear; hence the definition of the neutral point, that is, of the point in the airplane referred to which the longitudinal moment becomes independent of the angle of attack, does not apply to it.

3. Zero lift direction.- The change in zero lift direction, so important for the visibility conditions, amounts to $\pm 2^\circ$ with this arrangement. Notable also is the change in $\frac{dc_a}{d\alpha}$, which drops from 4.1 without brake to 2.8 with brake flaps, or almost by a third.

As to the advantages of mounting the brakes on top or under the wing it may be briefly stated that at vanishing lift the additional resistances are equal. For take-off, that is, for increasing c_a, the mounting on top of the wing would be more favorable since here, in contrast to mounting it under the wing the additional resistance still increases. Nevertheless one is forced to mount the brake under the wing because there only the rotation of the zero lift direction is in negative, that is, visibility improving, direction. Added to that, the diving moment is decisive for the strength of the wing against distortion. But, in turn, this is decreased only when the brake flap is mounted under the wing; the change of moment due to the brake acts, in this instance, unloading on the diving moment. One of the investigated intermediate solutions with brakes fitted on top and under the wing is constructively much more difficult to achieve.

b. Effect of Brake Span and Lateral Position

The employment of brake flaps conditions the appearance of a powerful wake behind the brake. The modern airplanes are fitted with some sort of trailing-edge flaps which are struck by the dead-air region. One will attempt to so dispose the span of the brakes that only one of these is struck. But, inasmuch as a definite

braking effect is to be achieved, a certain size is required.

The problem of effect of brake aspect ratio is therefore of as much interest as that of their lateral position.

The results of such measurements are shown in figures 3 and 4. Figure 3 is for brakes mounted on top and under the surface. In figure 4, where the brake is mounted under the wing, the effects of three different arrangements are visible:

1. Two aspect ratios in fuselage vicinity

2. Two aspect ratios approximately in the center of the semispan

3. Effect of the lateral position of brake

The additional resistances referred to brake area are shown in figure 5.

Comparing figure 1 with figure 3, the result is qualitatively the same. Quantitatively the additional resistance is also of the same order of magnitude (see fig. 2) but the variations in zero lift direction and in diving moment have decreased somewhat.

The data of figures 4 and 5 show very little difference. Neither the aspect ratio nor the lateral position has any appreciable effect on the additional resistance. On approaching the fuselage, like for an enlargement of the aspect ratio, the variation in zero lift direction and in the diving moment decreases. But the effects are so small compared to constructive considerations and wake effect problems, that they are not decisive.

II. EFFECT OF GAP BETWEEN BRAKE AND WING

For the practical design the question of minimizing the unwanted effects of the dead-air region was of greatest importance. Unfortunately the vibration phenomena occurring on the impacted flaps at the trailing edge (split flaps, ailerons) could not be investigated with the very heavily constructed wind-tunnel model, since it would have postulated at least approximate similarity of

elastic properties. Because the available model was designed according to standard practice and the design and construction of an elastically similar model was impossible within the allotted time, some wake studies behind brake flaps were made instead. The disturbed zone was scanned over its extent by total-head tube and tuft survey. These investigations like the tests with sailplane (reference 3) brakes appeared to be the most appropriate solution for reducing the dead-air region.

Figure 6 gives the results of total-head measurements (Δp_g) in the dead-air region behind the brake mounted under the wing, the region of maximum Δp_g being regarded as nucleus, and the region where Δp_g drops to zero as mixed region. The "spilling effect" through the slit in the plane of measurement behind the brake is plainly evidenced by a smaller Δp_g.

To explore the effects of the gap on the remaining aerodynamic quantities experiments were made on

a) A complete airplane model and

b) On a rectangular wing

The airplane model was the same used in the previously described tests. Two different types of brakes were measured (200 × 18.4 mm² or 1.65 percent of the wing area and 287 × 25 mm² or 3.2 percent of the wing area), the gap width being varied from zero to 1.33 times the height of the plate. The large surface was also farther away from the fuselage and farther back from the nose of the wing.

The rectangular wing (b = 1.50 m, t = 0.3 m, F = 0.45 m²) was of constant profile (maximum thickness 10 percent of chord at 30 percent chord and maximum camber 2 percent at 40 percent chord). The brake was 20 millimeters high and continued across the span, making its area 1.5 × 0.02 = 0.03 square meters or 6.67 percent of the wing area. Its distance back of the nose was 20 percent of the chord.

The test data are reproduced in figures 7, 9, and 11. The braking effect is shown in figures 8, 10, and 12 plotted against the width of gap along with the rotation of the zero lift direction and the displacement of the

diving moment. The two quantities are reduced to plate area = 1 percent of wing area for comparison.

The gap has, as is seen, little influence on the braking effect. Moreover, since the variations in zero lift direction and in diving moment become less, the presence of a gap is actually of advantage from the aerodynamic point of view.

The effect of rearward positon of plate, as reflected in figures 8 and 10 is also noteworthy; in figure 10 it results in a loss of braking effect, although in coincidence with a decrease in zero lift direction and diving moment change. Nevertheless it is more beneficial if the design permits the plate to be located farther forward, where less area is required and the slight impairment of the other characteristics is balanced by smaller plate dimensions.

The comparatively low braking resistance of the rectangular wing is due to the fact that the interference effect of the brake flap cannot extend spanwise. The rectangular wing therefore exemplifies the plane problem.

III. PRESSURE DISTRIBUTION ABOUT A PROFILE WITH BRAKE FLAPS

The previously mentioned change in longitudinal moment in the presence of a brake flap carries a prefix contrary to expectations: The mounting under the wing effectuates a tailheavy moment. This phenomenon is illustrated on pressure distribution measurements, which moreover are valuable for static investigations as well, since the customary calculation methods for predicting the pressure distribution about a profile fail when diving brakes are involved.

These measurements had been made in the Göttingen laboratory before the Heinkel wind tunnel was completed. The employed rectangular wing had a 1.0-meter span by 0.25-meter chord. Its constant profile had a maximum camber of 2.4 percent of the chord (at 40 percent chord), and a maximum thickness of 16.5 percent of the chord. The pressure measurements were made at midspan of the wing at $v = 30$ meters per second. The brake flap was mounted at 48 percent of the chord.

The result is shown in figure 13. There is a distinct pressure before the flap. The tailheavy moment, however, is due to the not inconsiderable low pressure behind the flap. The effect of this low pressure predominates. The local pressure jump induced by the flap is of the order of the dynamic pressure.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

REFERENCES

1. Muttray, H.: Über die Grosse der Berichtigungsbeiwerte für Widerstand und Anstellwinkel bei Freistrahlen von elliptischem Querschnitt. Luftfahrtforschung, Bd. 12 (1935) Lfg. 8, p. 265.

2. Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen, II. Lieferung, München 1923, Verlag Oldenbourg, p. 34, Zahlentafel 41.

3. Jacobs, Hans, and Wanner, Adolf: DFS Dive-Control Brakes for Gliders and Airplanes. T.M. No. 926, NACA, 1940.

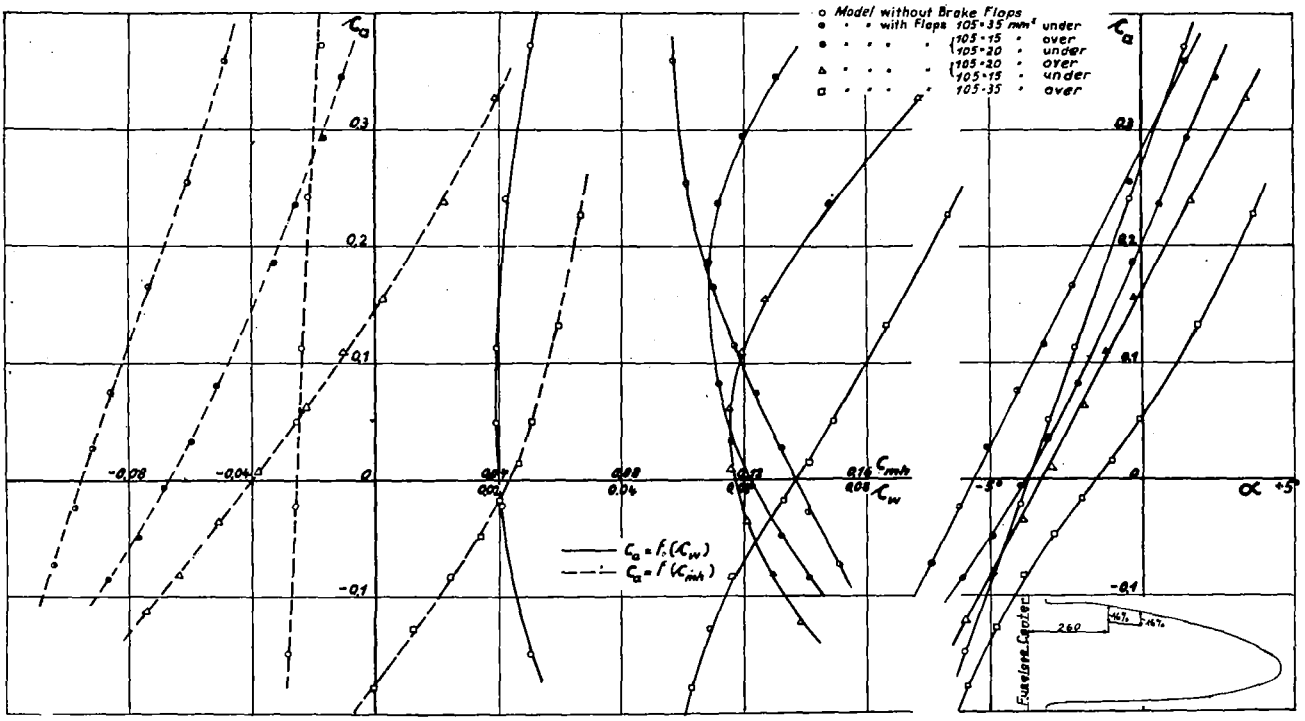

Figure 1.- Diving brakes mounted on top and under the wing.

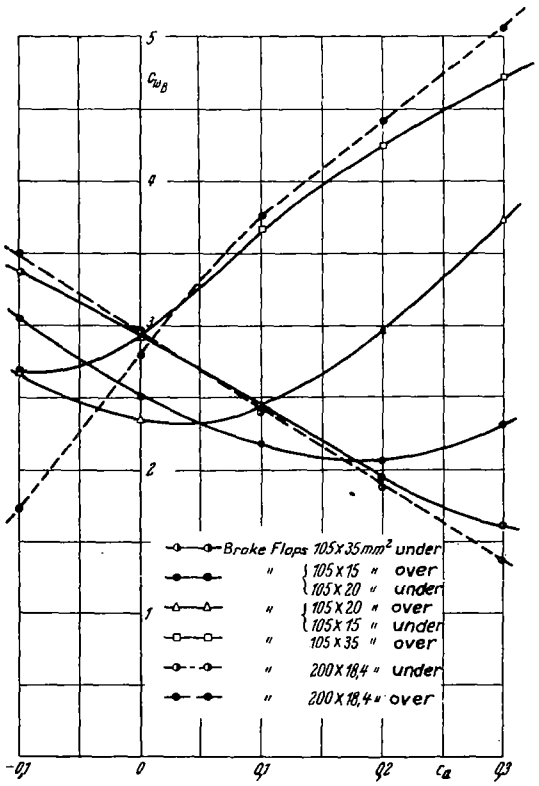

Figure 2.- Braking effect of diving brakes mounted on top and under the wing; effect of mounting at different positions.

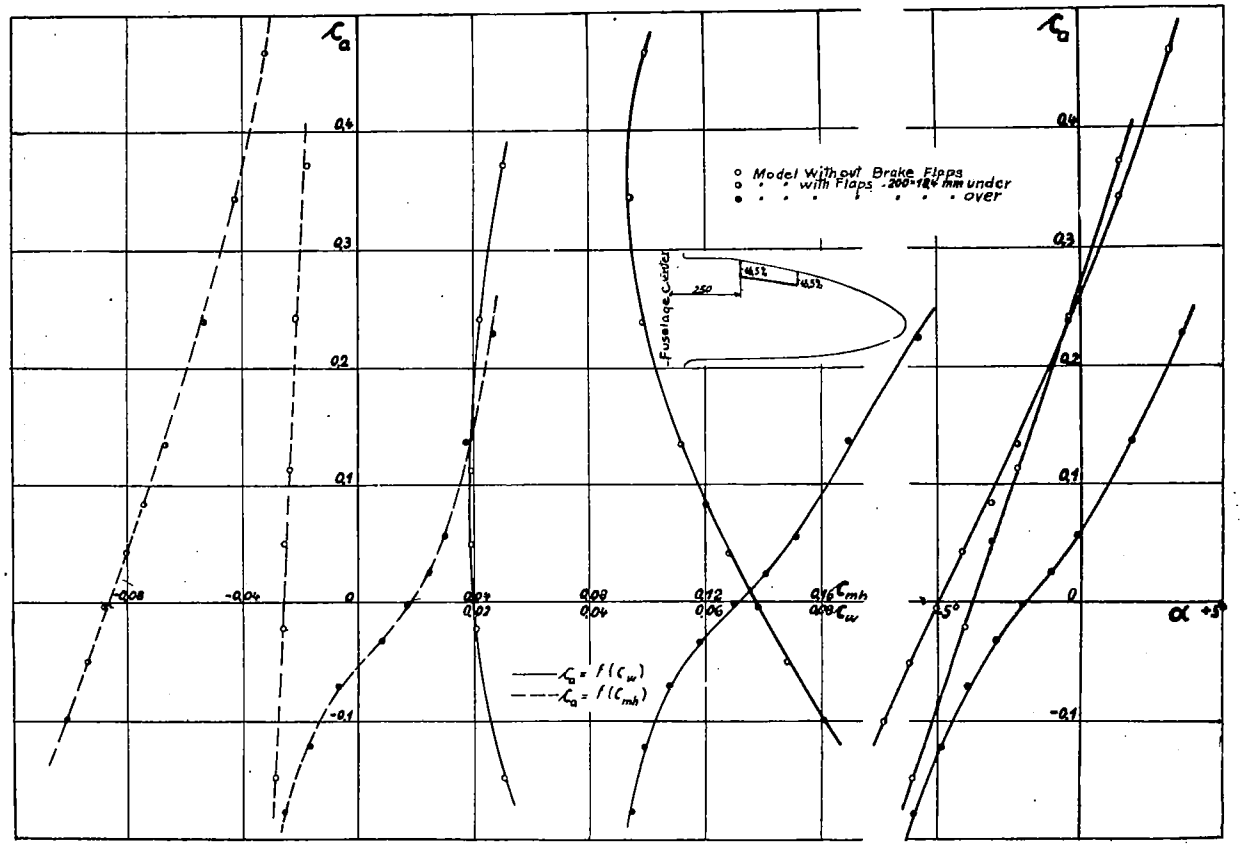

Figure 3.– Diving brakes on top and under the wing.

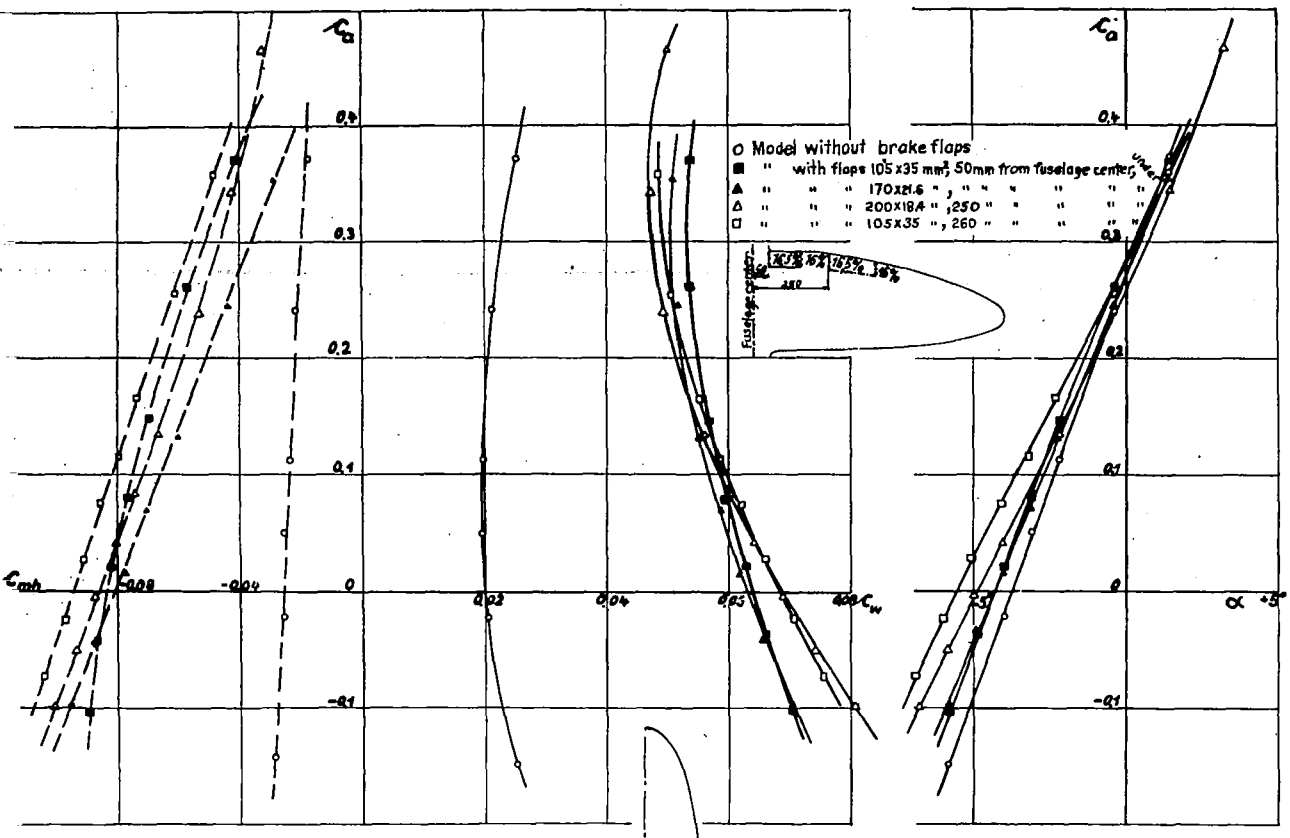
o Model without brake flaps
■ " with flaps 105 x 35 mm², 50mm from fuselage center
▲ " " " 170x21.6 " , " " " " " "
△ " " " 200x18.4 " ,250 " " " " "
□ " " " 105x35 " , 260 " " " " "
Fuselage center
Cmah
Cwg
α

Figure 4.- Brakes of different spans and at various positions.

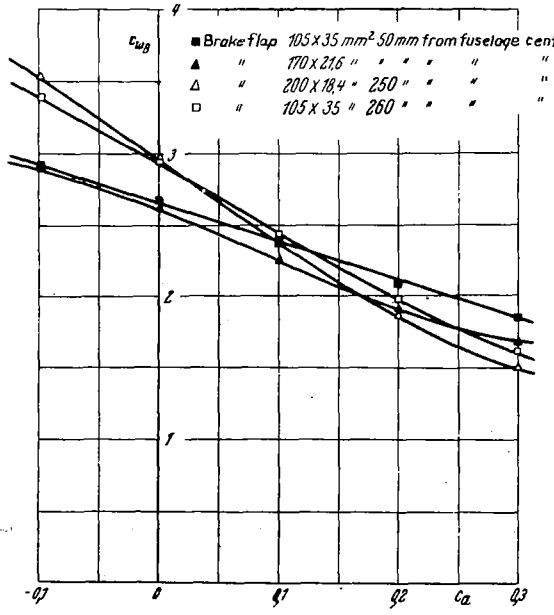

Figure 5.- Braking effect with brakes of different spans and positions.

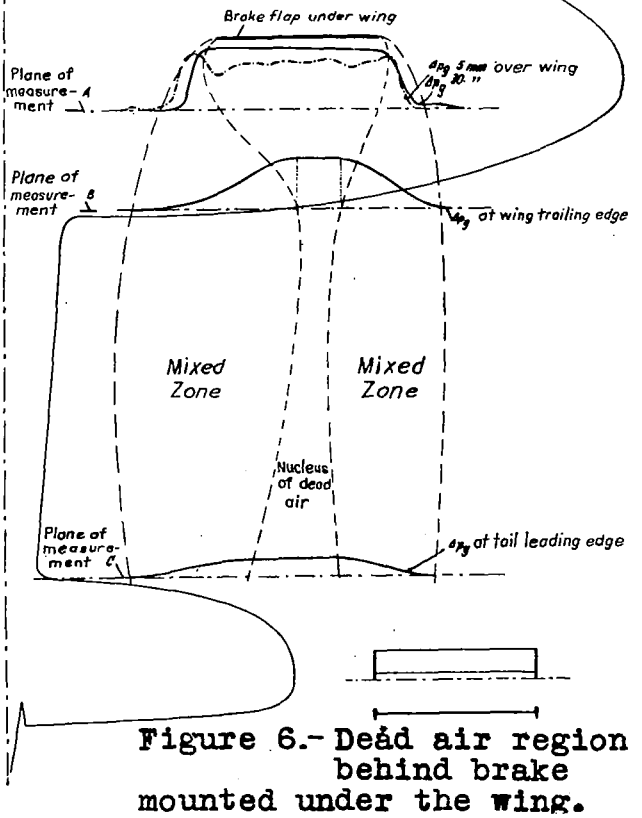

Figure 6.- Dead air region behind brake mounted under the wing.

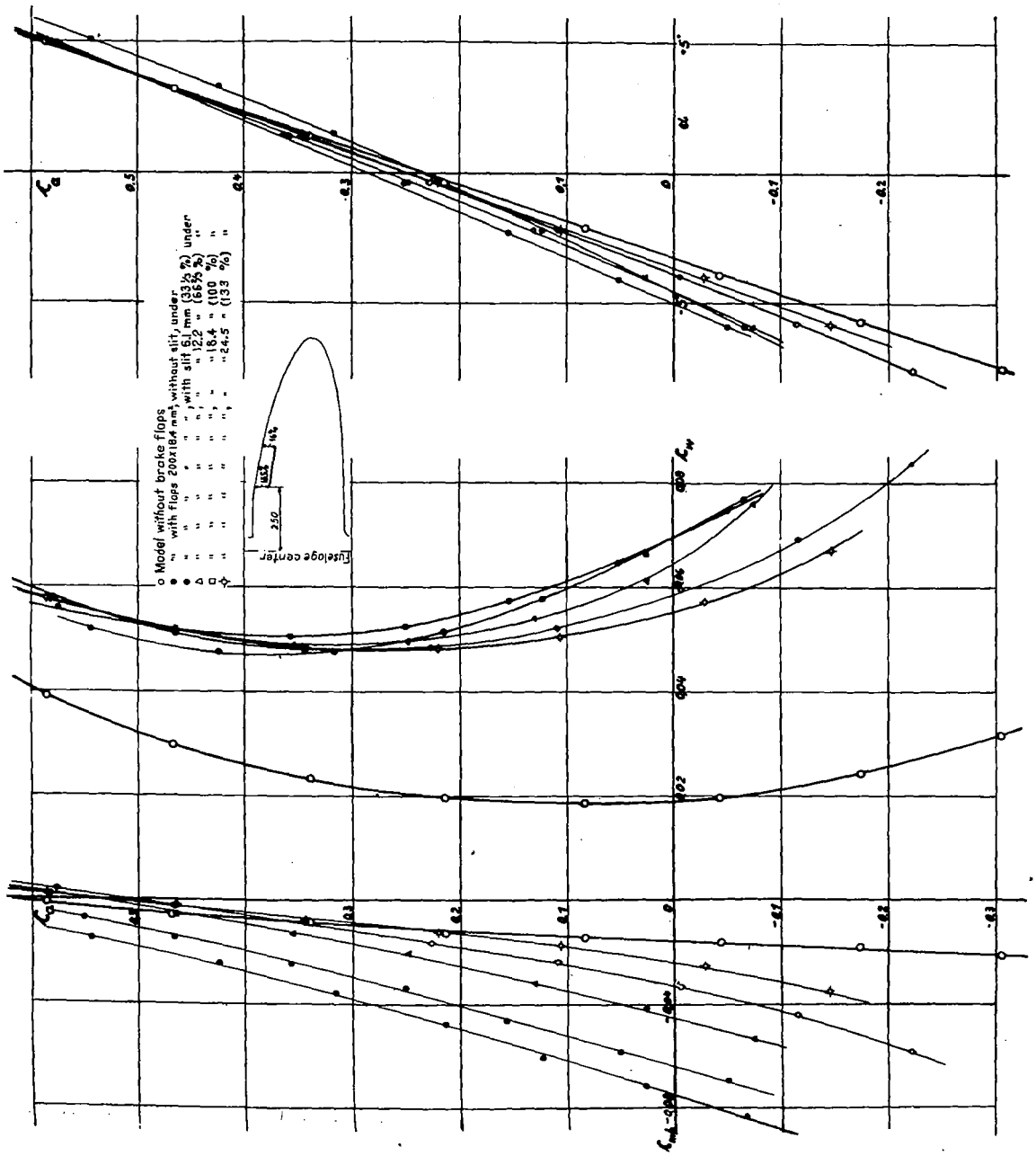
o Model without brake flaps
with flaps 200x184 mm, without slit, under
" " " " " " with slit 61 mm (33⅓ %) under
" " " " " " " 122 " (66⅔ %) "
" " " " " " " 184 " (100 %) "
" " " " " " " 245 " (133 %) "
Fuselage center
250
184
61
c_a
c_w
c_{w_0}
$c_{w_{-20°}}$
α

Figure 7.- Brakes with different gap widths.

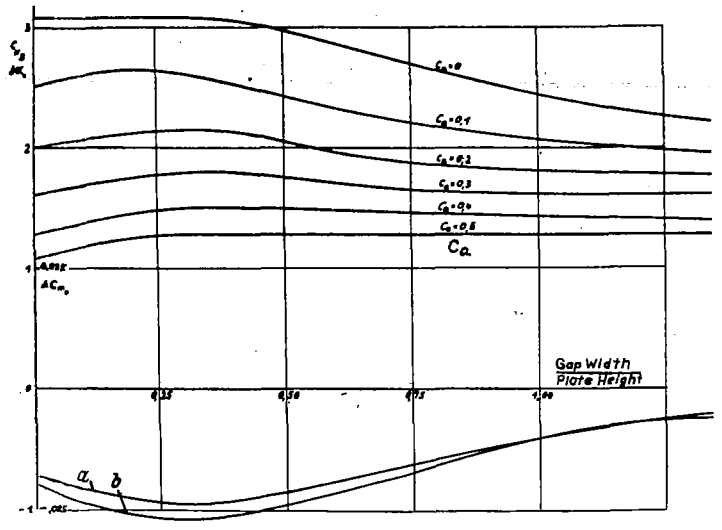

Figure 8.- Braking effect, change of zero lift direction and of diving moment with various gap widths. (to Fig. 7)
a Δc_{m_0} (brake = 1% wing area)
b $\Delta\alpha_0$

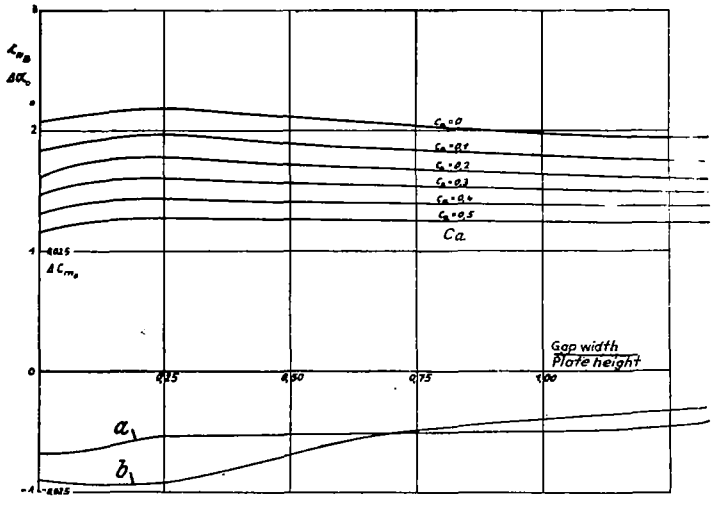

Figure 10.- Braking effect- change in zero lift direction and diving moment. (to Fig. 8)
a Δc_{m_0} (brake = 1% wing area)
b $\Delta\alpha_0$

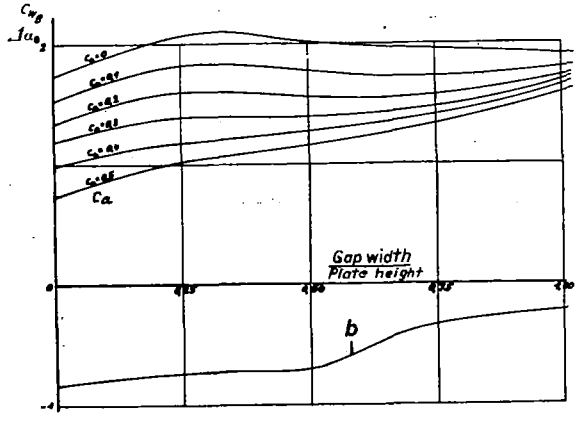

Figure 12.- Braking effect and change in zero lift direction. (to Fig. 11)

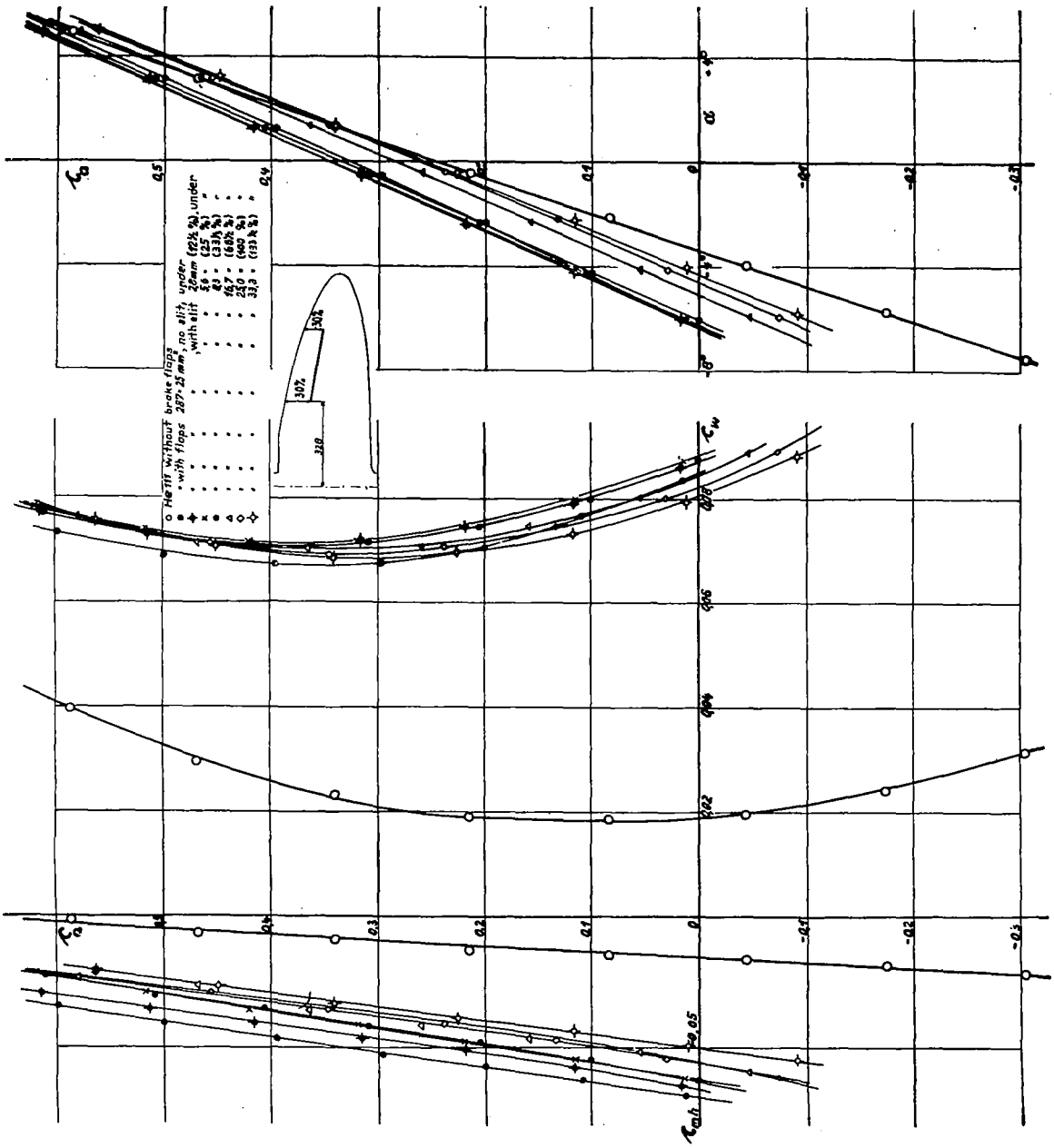

Figure 9.- Larger brakes with gap.

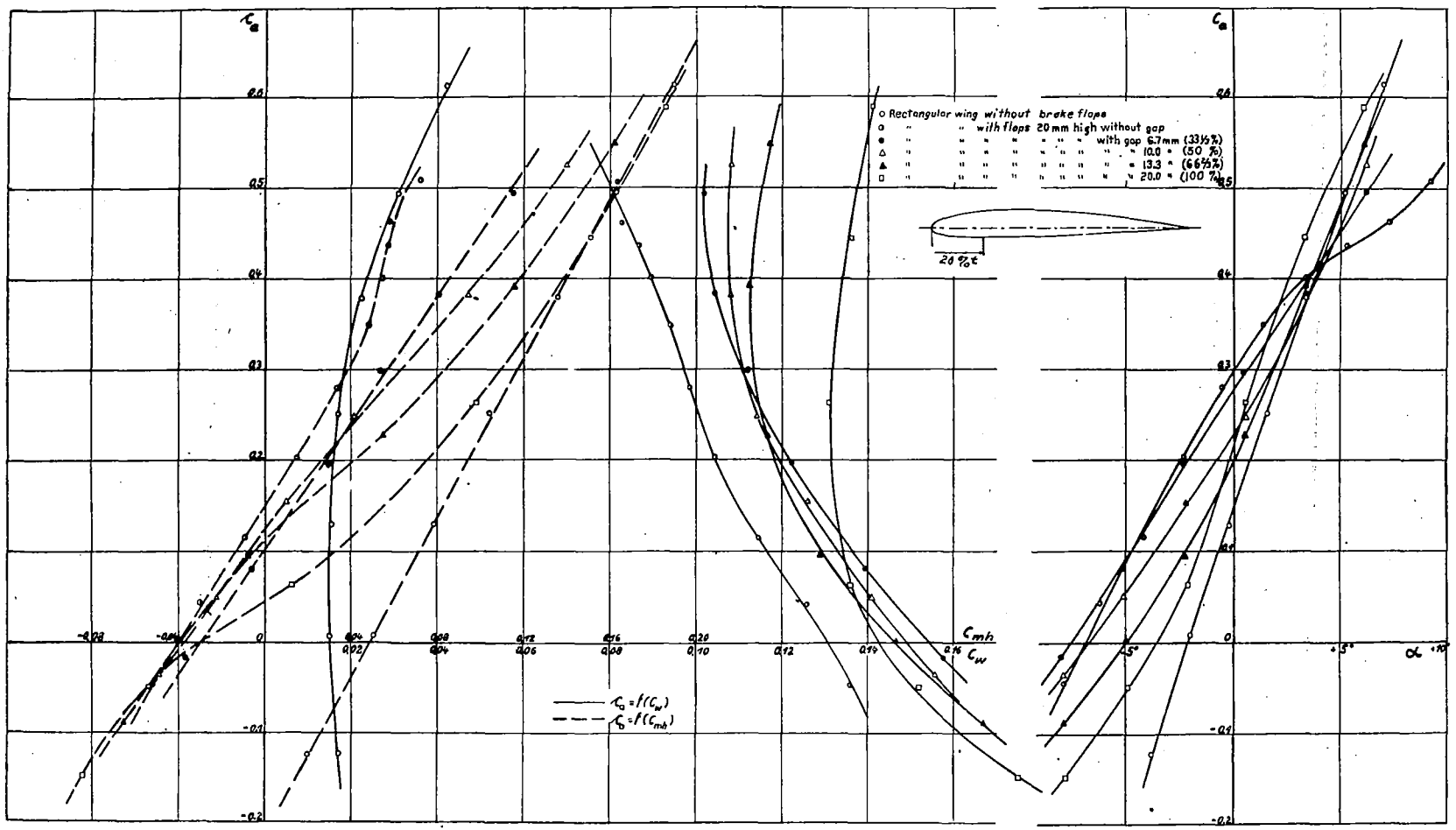

Figure 11.- Rectangular wing with continuous brakes and various gap widths.

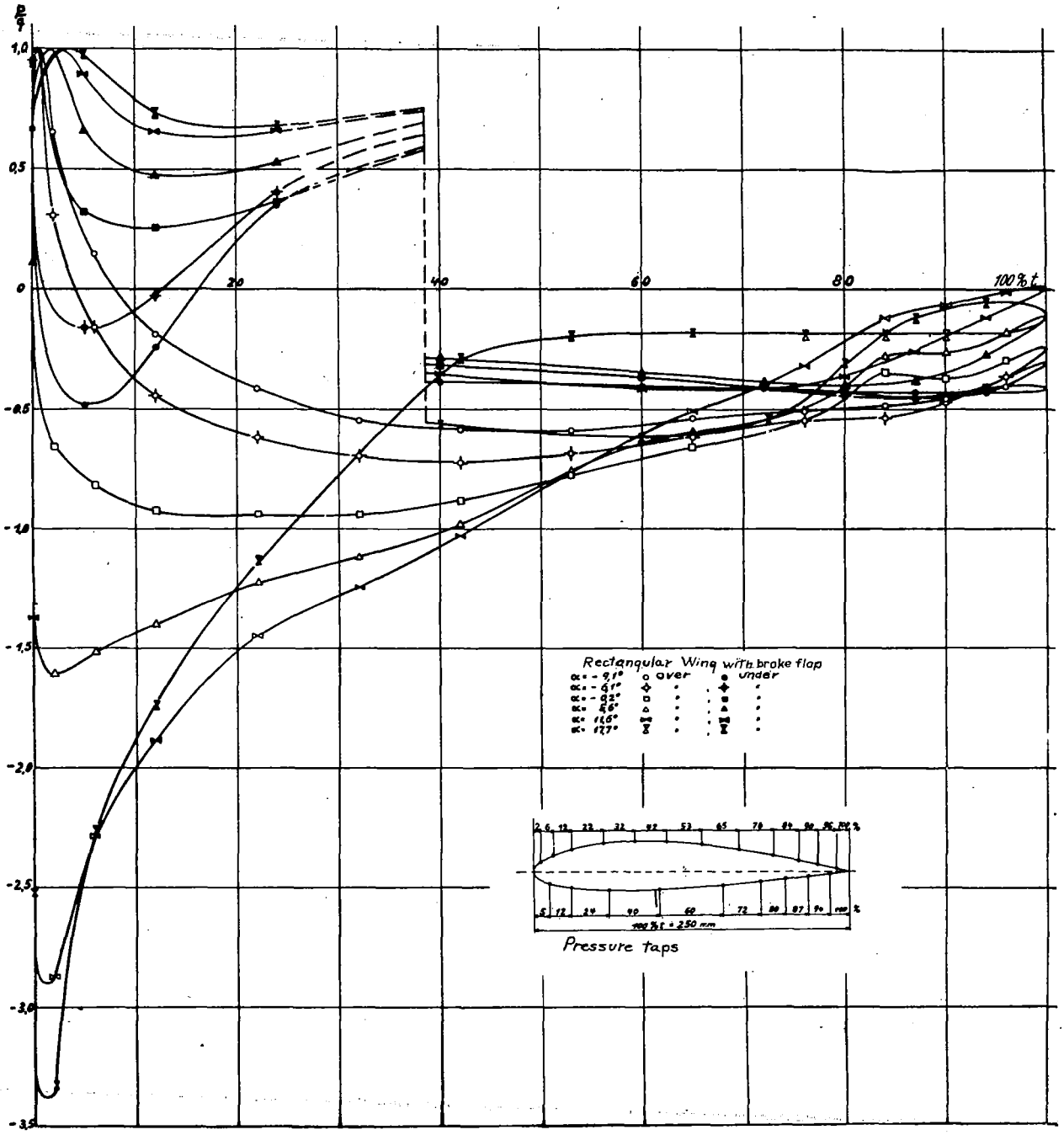

Figure 13.- Pressure distribution on rectangular wing with brake.

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